Measurements of total cross-sections at RHIC

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RHIC Topical Workshop:
Estimating Npart and Ncoll

Outline

1. ZDC common detectors (previous talk)

2. All experiments supplement with something else to detect hadronic events

3. ZDC's also detect Mutual Coulomb Dissociation

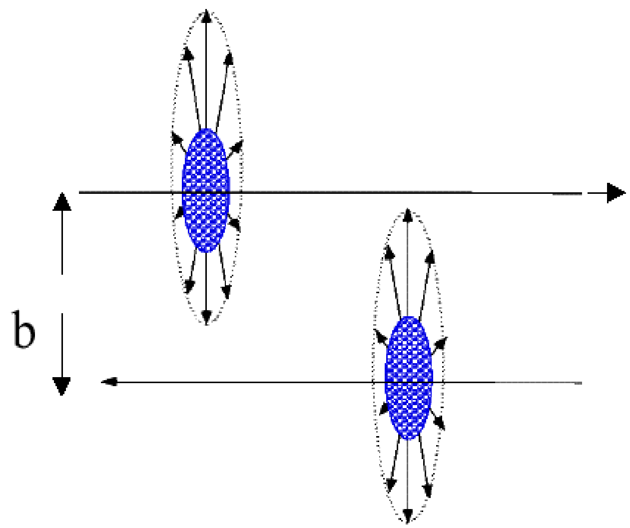
    a. Well-understood theoretically

    b. Measurements of *ratios* to total cross section

        I. In agreement between experiments

        II. In agreement with theoretical predictions

How Do We See Collisions at RHIC?



Types of Collisions

- Hadronic (n-n)
- Coulomb Dissociation (γ-N)
- pomeron exchange
- photon exchange (γ-γ)

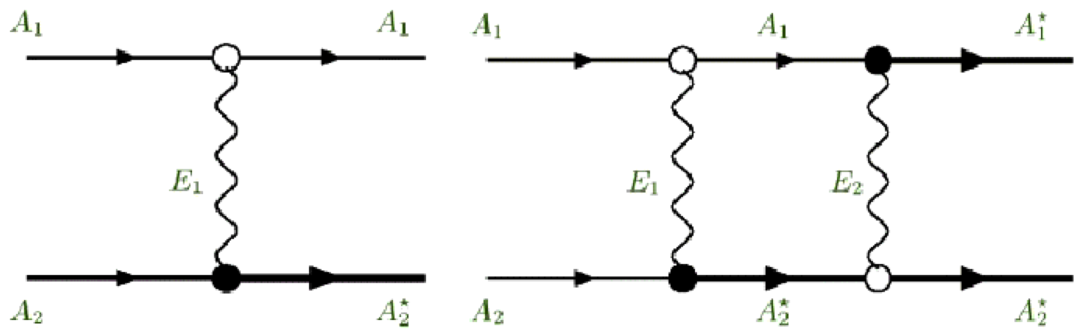
Common Detectors

- BRAHMS ZDC
- PHENIX ZDC
- PHOBOS ZDC
- STAR ZDC

Different Detectors

- PHENIX Beam Beam Counter
- PHOBOS Paddle Counter
- Brahms Beam Beam Counters
- STAR Central Trigger Barrel

Coulomb Dissociation 1



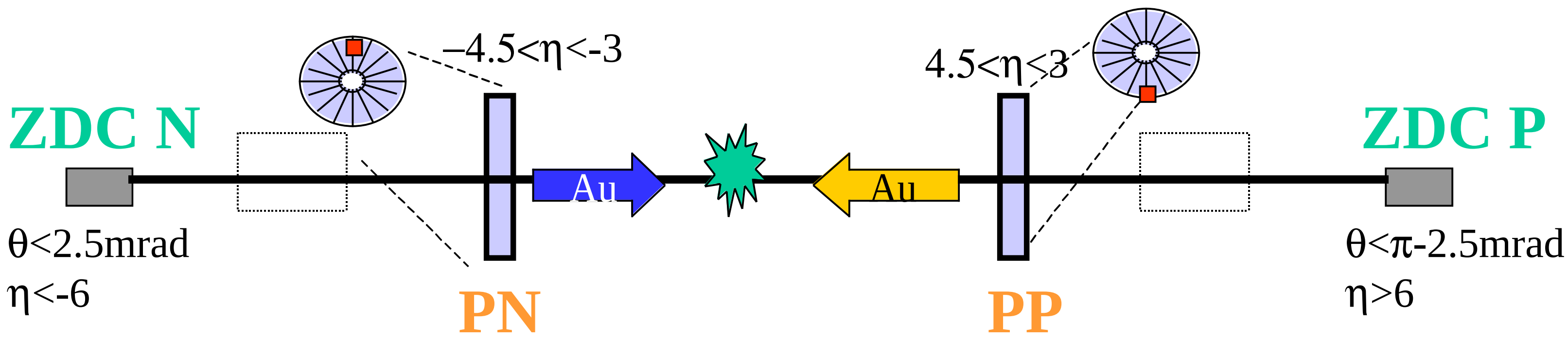
Weizsäcker-Williams Method

[1] A.J.Baltz, M.J.Rhoades-Brown, J.Weneser, PRE 54 (1996) 4233
[2] A.J.Baltz, S.N.White, RHIC/DET Note 20, BNL-67127 (1996)
[3] S.N.White, Nucl. Instrum. Meth. A409, 618 (1998)
[4] A.J.Baltz, C.Chasman, S.N.White, Nucl. Instrum. Meth. A417, 1 (1998)
[5] I.A. Pshenichov, J.P.Bondorf, I.N.Mishustin, A.Ventura, S.Massetti, nucl-th/0101035

γ-N

Single Coulomb Dissoc. : σ(Au + Au -> Au + Au*) ~ 92 barns
Mutual Coulomb Dissoc. : σ(Au + Au -> Au* + Au*) ~ 3.6 barns

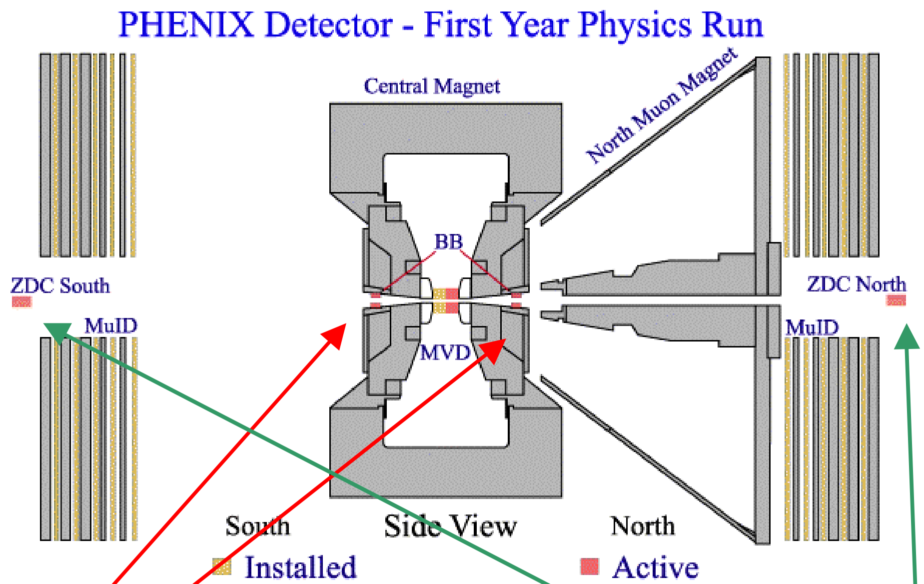
Phobos Trigger & Event Selection



Event sample	trigger	online requirements	offline selection
Hadronic events	PN,PP $\Delta t < 10ns$	PN > 0 AND PP > 0	good zdc timing
Coulomb events	ZDCN, ZDCP $\Delta t < 80ns$	ZDC N > 0 AND ZDC P > 0 AND PN = 0 AND PP = 0	

→ 2 different data sets

PHENIX MinBias Triggers



BBCs

- Array of 64 quartz cerenkov radiators
- 1.5 meters from IP
- $3<\eta<4$
- required a coincidence between N and S, with > 1 hit in each arm.
- $92 \pm 2\%$ efficiency for hadronic collisions

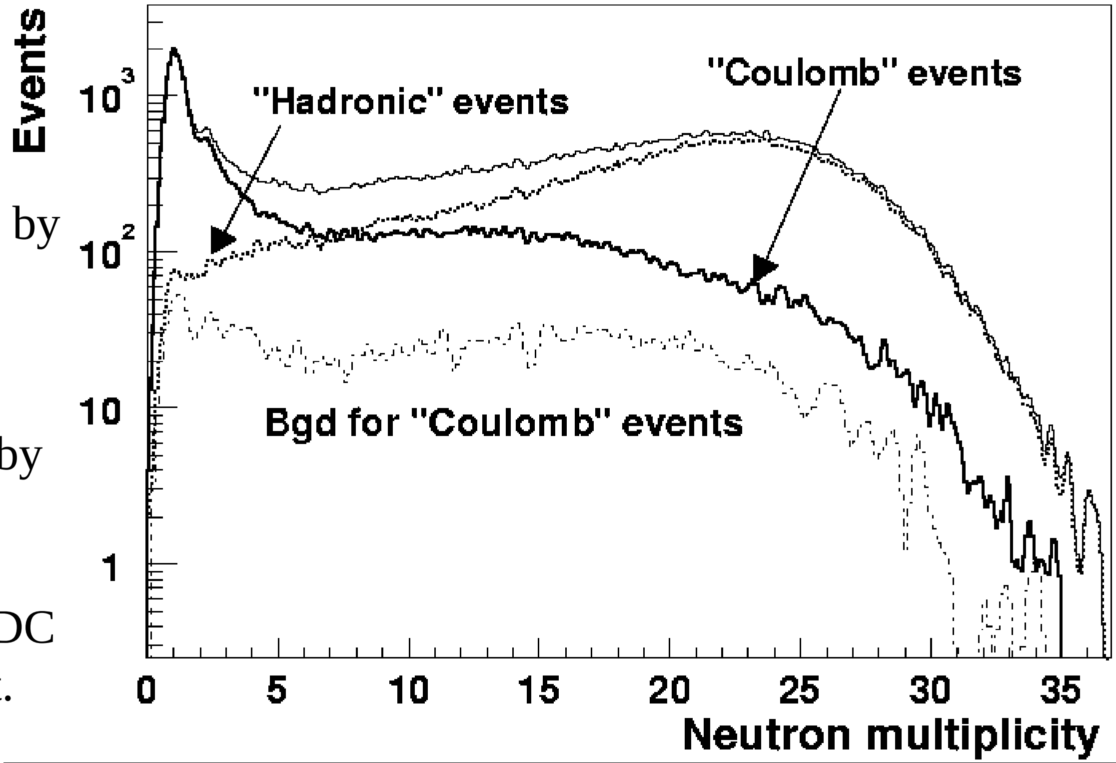
ZDCs

- 2 Small Forward Hadron calorimeters
- $|\theta| < 2.5$ mrad
- required a coincidence between N and S
- >99% efficient for Coulomb Events*
- $98 \pm 2\%$ efficient for BBC Triggered Events

ZDC Spectrum

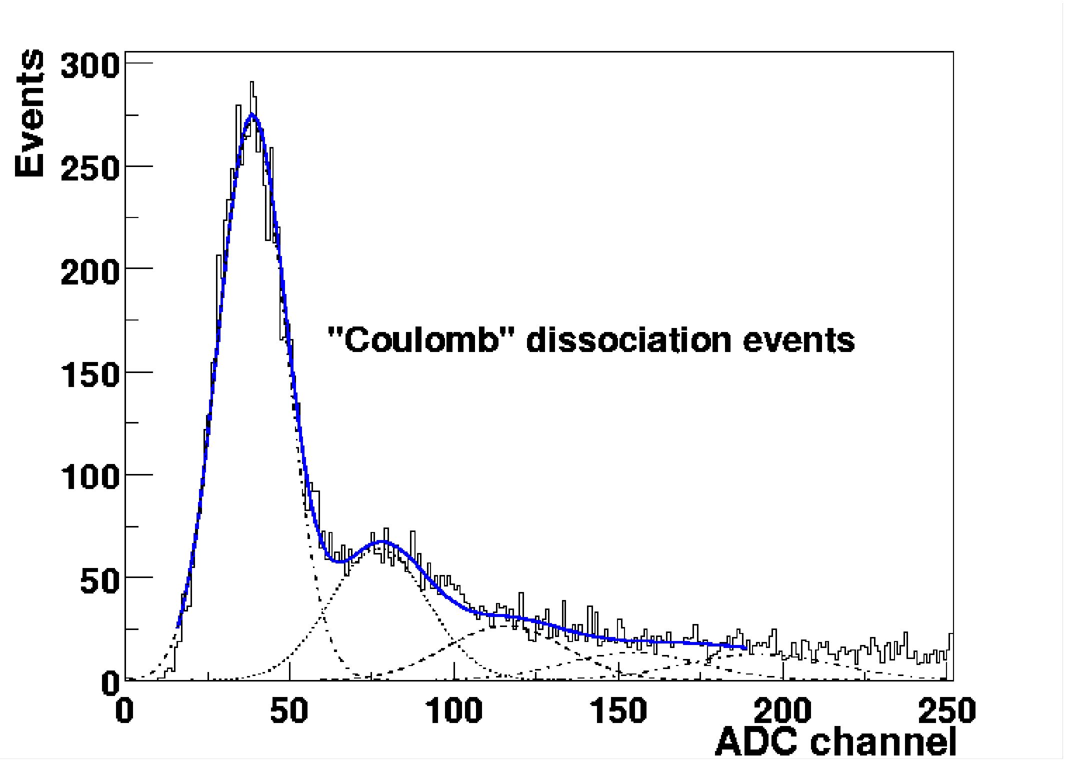
Single Arm of ZDC with Cuts using PHENIX Triggers (BBC, ZDC)

- Large differences in the behavior between Coulomb and Hadronic Events.
- Hadronic events are tagged by the BBC (in PHENIX), Coulomb Events by ZDC*!BBC
- Background is determined by looking at low multiplicity BBC Triggers, and cross-checked with a sample of ZDC triggers with a 1 neutron cut.



Neutron Mult. in Coulomb Events

•“Coulomb” ZDC spectrum generated with a 1n cut on the other side
•Neutron multiplicities comes from simultaneous gaussian fit.
•Dominant systematic error comes from sensitivity to fitted lineshape. Detector resolution should vary as √ N, and systematic errors are derived from relaxing this constraint.

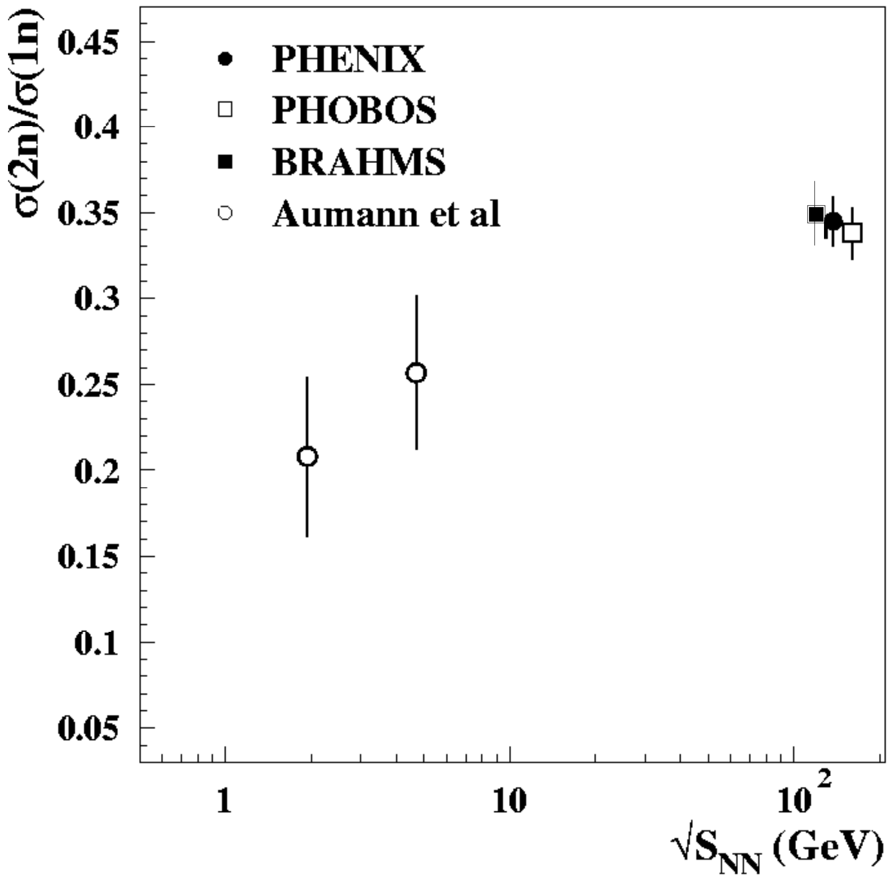


Phobos systematic uncertainties

ZDC energy resolution for single neutron:		20.6 %
ZDC efficiency for hadronic events:		98+/- 2%
Uncertainty on $\sigma_{hadronic}$		3 %
Uncertainty on $\sigma_{coulomb}$	random coincidences:	4 %
	single beam interaction:	0.4 %

Ratio of 2n/1n in Coulomb Events

- Previous measurements done by Aumann et al, PRC 47, 1728 (1993)
- Errors include statistical and systematic folded in quadrature
- Good agreement among 3 experiments.



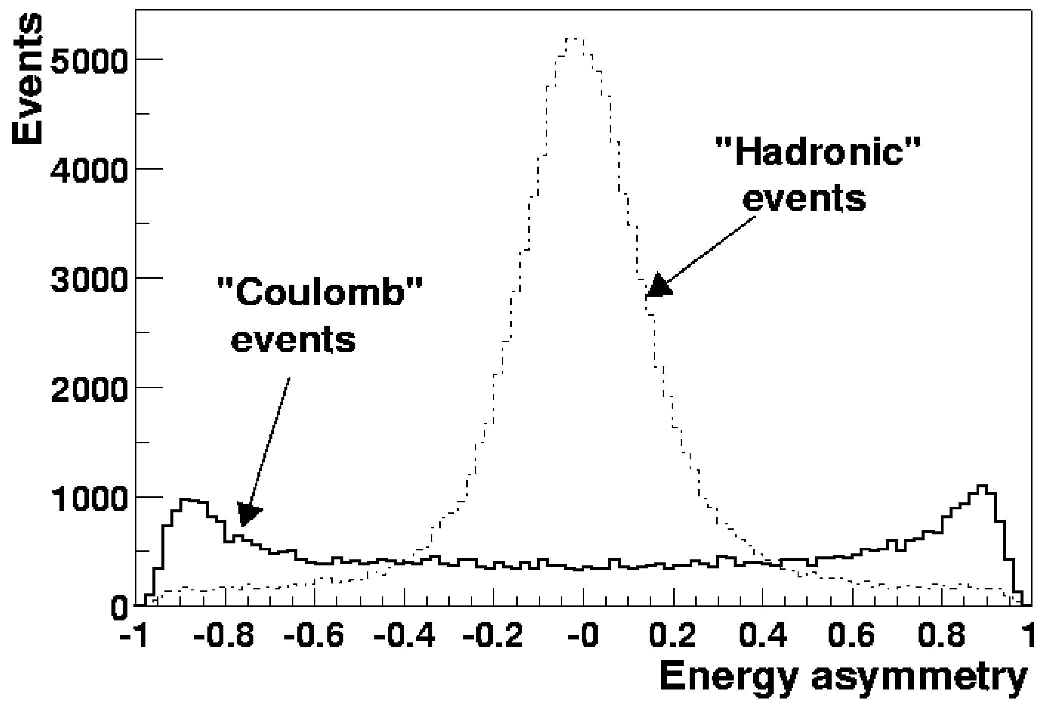
Comparisons

σ_i (barns)	Theory (1)	Theory (2)	PHENIX	PHOBOS	BRAHMS
σ_{tot}	10.8 ± 0.5	11.19	N.A.	N.A.	N.A.
σ_{geom}	7.09	7.29	N.A.	N.A.	N.A.
$\frac{\sigma_{geom}}{\sigma_{tot}}$	0.67	0.659	0.661 ± 0.014	0.658 ± 0.029	0.68 ± 0.06
Coulomb					
$\frac{\sigma(1n,Xn)}{\sigma_{tot}}$	0.125	0.139	0.117 ± 0.004	0.123 ± 0.011	0.121 ± 0.009
$\frac{\sigma(1n,1n)}{\sigma_{1n,Xn}}$	0.329	–	0.345 ± 0.012	0.341 ± 0.015	0.36 ± 0.02
$\frac{\sigma(2n,Xn)}{\sigma_{1n,Xn}}$	–	0.327	0.345 ± 0.014	0.337 ± 0.015	0.35 ± 0.03

(1) A.J.Baltz, C. Chasman, S.N.White, NIM A 417, 1, (1998) nucl-ex/9801002
(2) I.A. Pshenichnov, J.P.Bondorf, I.N. Mishustin, A. Ventura, S. Masetti, nucl-th/0101035
and I. Pshenichnov, private comm.

Tagging Processes

- Hadronic events have correlated neutron multiplicities, since the two nuclei have the same number of wounded nucleons.
- Nuclei in Coulomb events interact independently with field.
- Well-defined variable, with a quantifiable background.
- Provides a Technology for tagging photonuclear processes (and pomeron mediated,…)



Energy Asymmetry

$$A(E_{left}, E_{right}) = \frac{E_{left} - E_{right}}{E_{left} + E_{right}}$$

Conclusions

•The ratio of the hadronic to the total cross-section as seen by the ZDC has been measured, and is found to be

$$\sigma_{had} / \sigma_{tot} = 0.67 \pm .07$$

in good agreement with theoretical calculations.

•The neutron multiplicity distribution from coulomb dissociation has been measured and is also in good agreement with calculations (< 10%).

•ZDC's also provide a calibrated detector for triggering on many processes, eg, pomeron exchange, and is useful for photon tagging in p-p and p-A, etc...